

# Status Report on Development of Random Polishing Process

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***Mirror Technology Days***  
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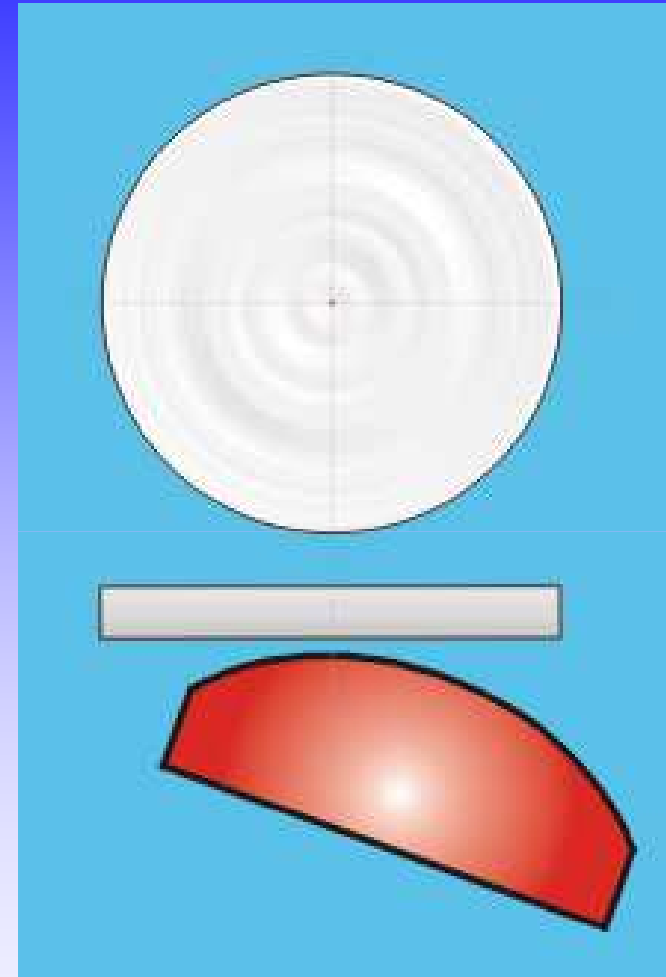


# Outline

- Brief overview of the Zeeko process and the random tool path
- Possible applications of the random tool path
- Polishing experiments with the random tool path
- Future work

# Basis of the Zeeko Polishing Process

- Spherical “bonnet” creates a localized area of material removal of variable size (“influence function”)
- Spot size is controlled independently by varying:
  - The axial position of the tool WRT the part, and therefore the degree to which the membrane is compressed against the part
  - The internal pressure of the working fluid within the tool is controlled separately



# Tooling

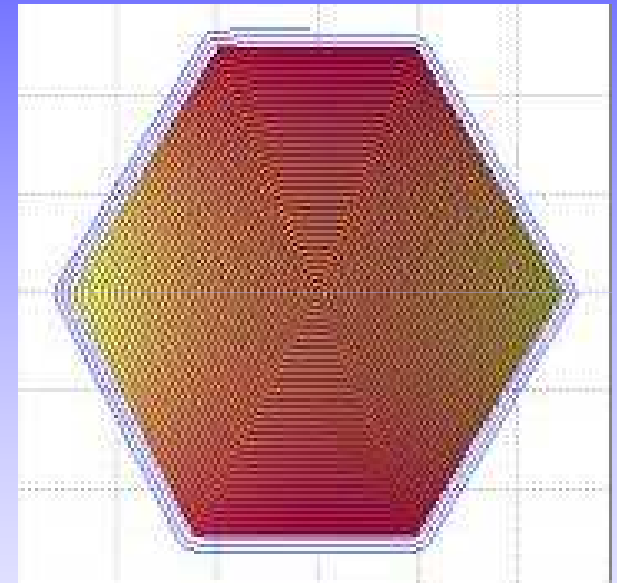
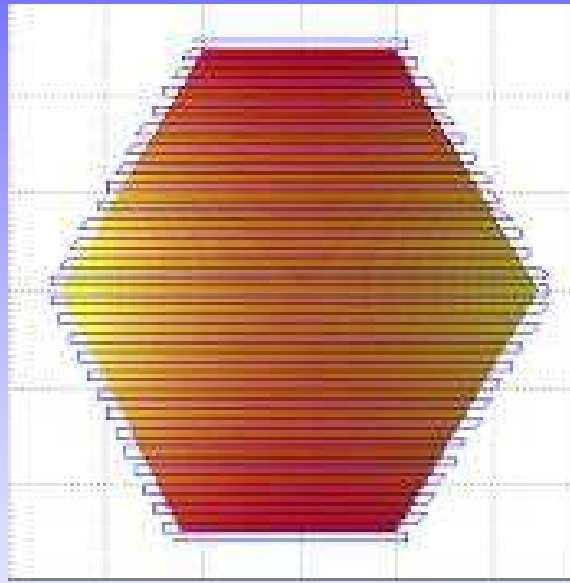
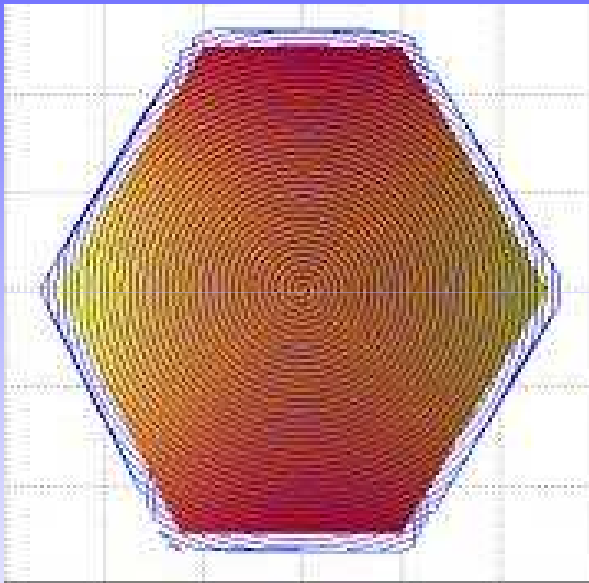
## The spherical bonnet tooling:

- is covered with standard polishing pads (e.g. polyurethane)
- is pressed into the surface of the workpiece by displacement  $\Delta z$ , creating a contact spot of known diameter
- is worked with standard polishing consumables (e.g. cerium oxide)
- delivers volumetric removal rates up to a few cubic millimeters per minute

# Zeeko Polishing Modes

- Pre-polishing – uniform removal across surface with constant feed rate
- Corrective Polishing – the tool's dwell time is varied to provide a prescriptive polish
- “Grolishing” – a diamond pad is used to severely abrade the surface as a polishing process. This replaces the usual pads and polishing slurries.

# Tool paths

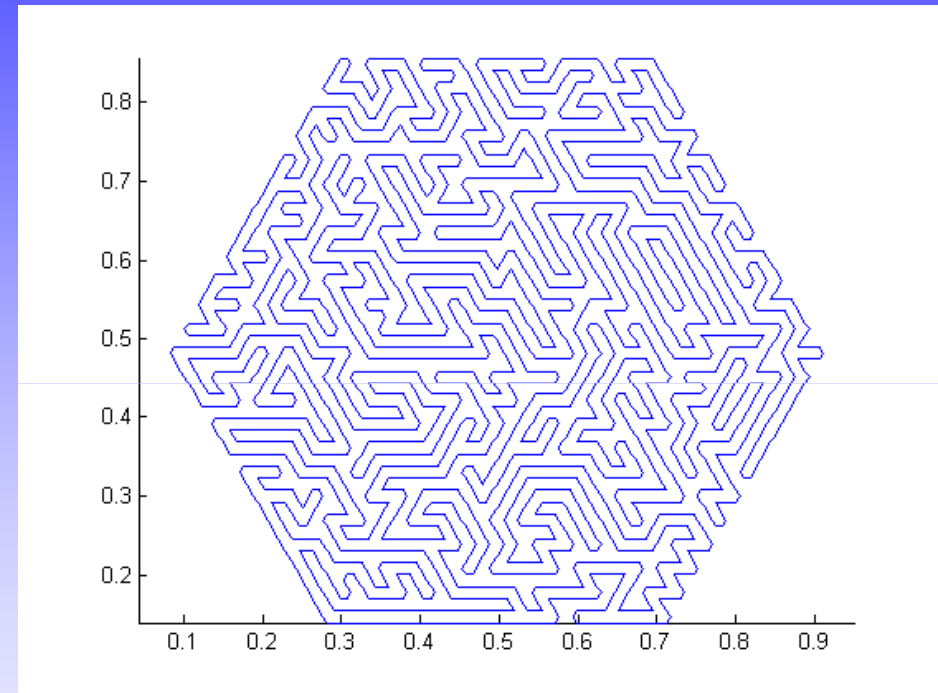


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# The unicursal random tool path

- Never crosses itself
- Completely new pattern with each iteration
- Can be used with any continuous surface
- This tool path is compatible with Zeeko's *Precessions* software for corrective polishing



# A comparison between raster and random tool paths

- Two 20-mm diameter spots were polished on a pitch-polished flat part
- The pattern spacing on both paths was 0.35 mm.
- All other parameters were equal.

Feed rate: 100 mm/min  
H-axis speed: 300 rpm  
Precess angle: 15°  
10 mm spot

80 mm bonnet  
Z-offset: 0.16 mm  
Polishing time: 30 min

# Raster polished region

C:\Copy of MapvueAE\Data\TEMP.map

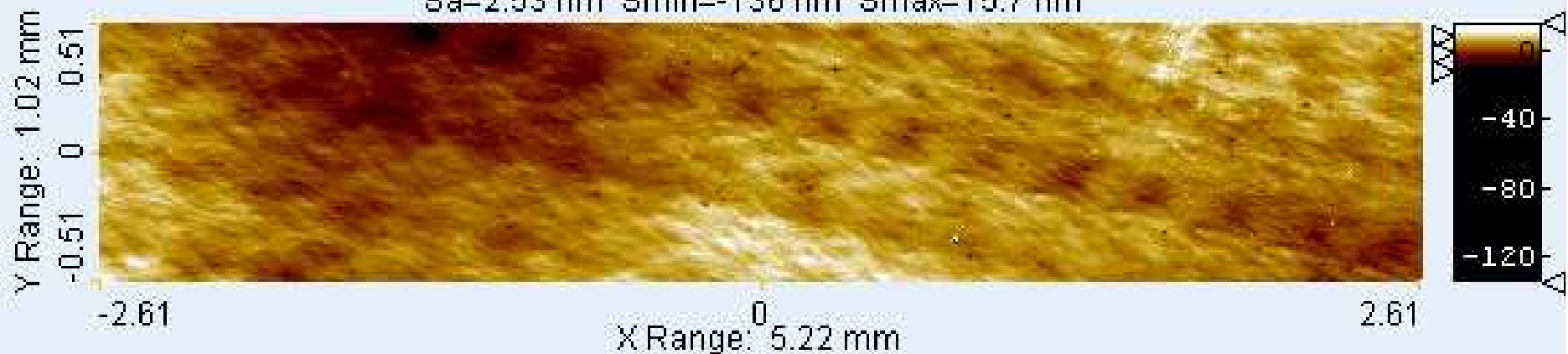
Sa=2.99 nm Smin=-11.7 nm Smax=22.3 nm



# Random polished region

C:\Copy of MapvueAE\DataC:\Copy of MapvueAE\Data\TEMP.map

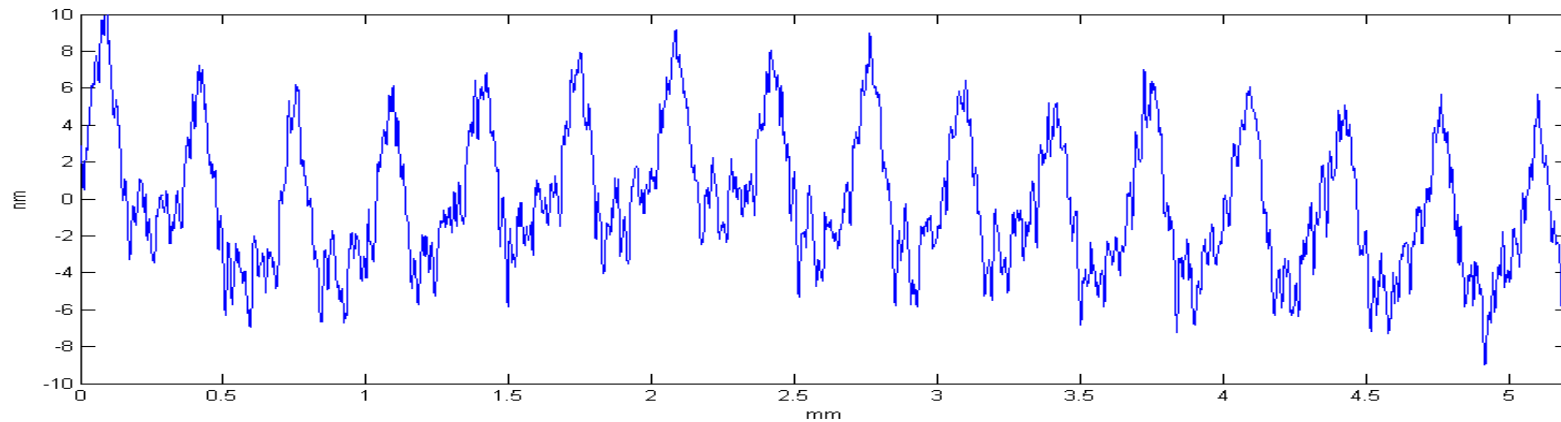
Sa=2.53 nm Smin=-136 nm Smax=15.7 nm



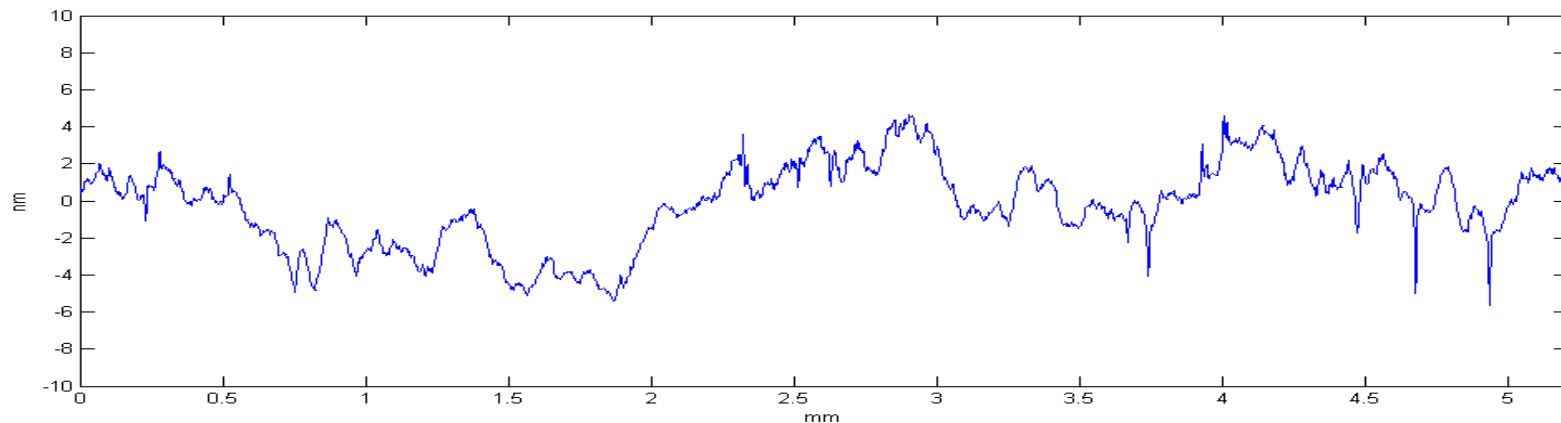
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# Raster polished region profile



# Random polished region profile



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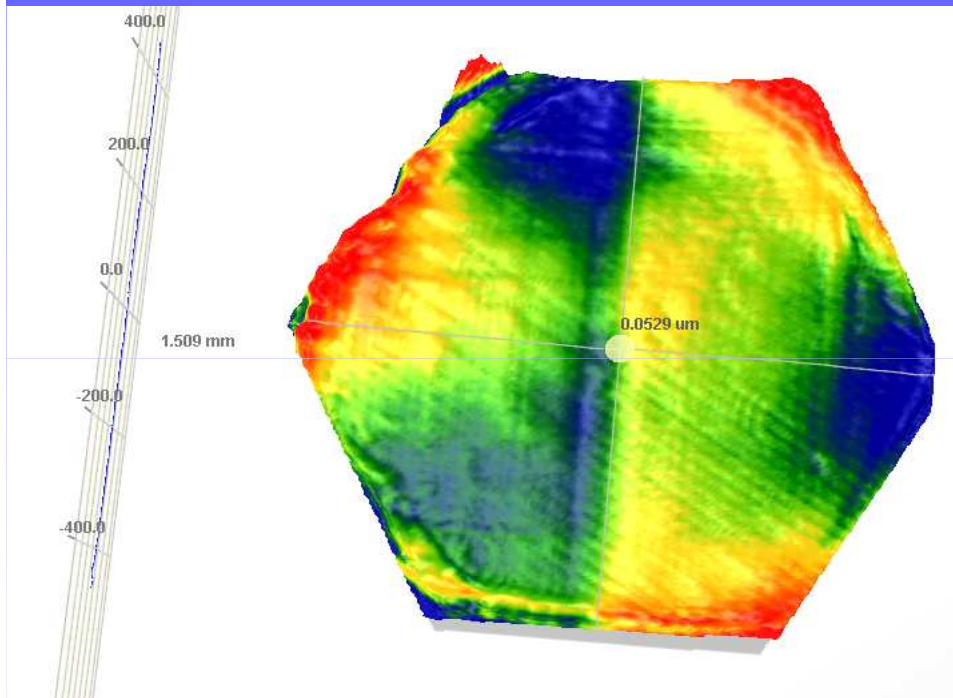


# Possible Applications of the Random Tool Path

- Pre-polishing: remove a uniform-depth layer of material across the entire surface to correct sub-surface damage
  - High removal rates desirable
- Surface clean-up: remove a uniform-depth layer of material to clean up surface after corrective polishing
- Corrective polishing

# Fabrication of Large Telescope Mirror Segments

- Removing sub-surface damage on such a large part requires a high removal rate
- Groishing removes material efficiently, but leaves a strong signature.

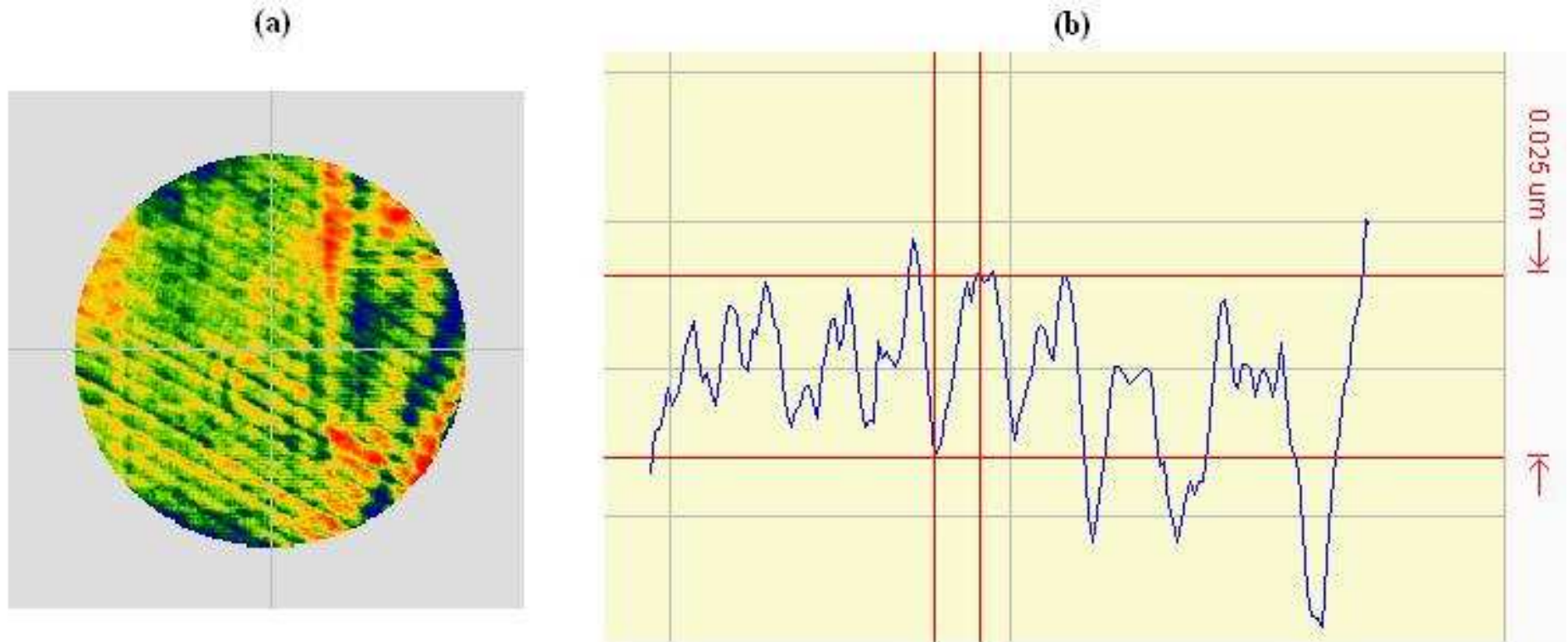


Result from Guoyu Yu, OpTIC Technium

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# Raster marks left by polishing process



Result from Guoyu Yu, OpTIC Technium

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# Uniform Removal with the Random Tool Path

- Polished a 60-mm diameter circle on 80-mm diameter plano part
- 24 minute polishing program
- H-axis speed: 200 rpm
- Feed rate: 750 mm/min
- Four precess positions (angled at 15°)

**Surface Statistics:**

Ra: 99.65 nm  
Rq: 118.93 nm  
Rz: 540.98 nm  
Rt: 553.62 nm

**Set-up Parameters:**

Size: 736 X 480  
Sampling: 160.54  $\mu\text{m}$

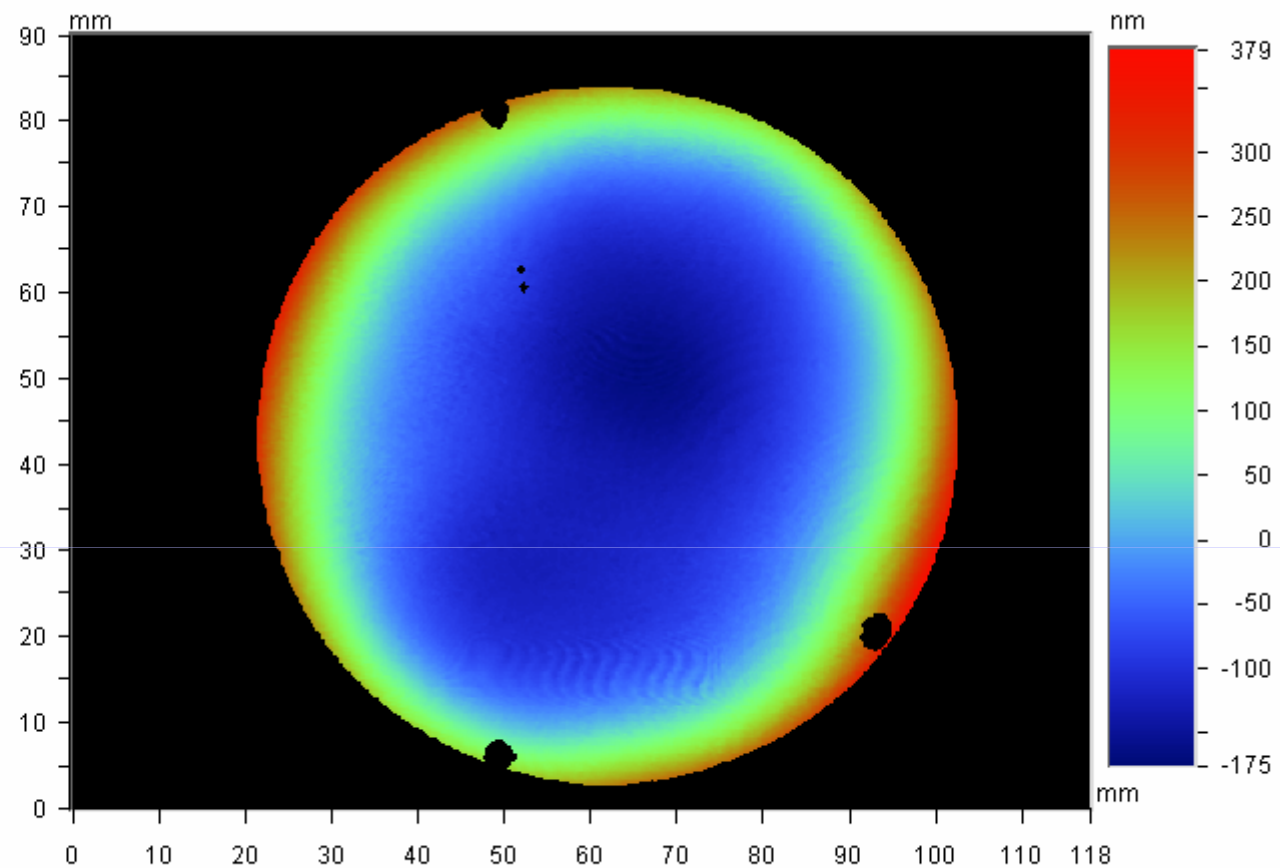
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Tilt

Filtering:

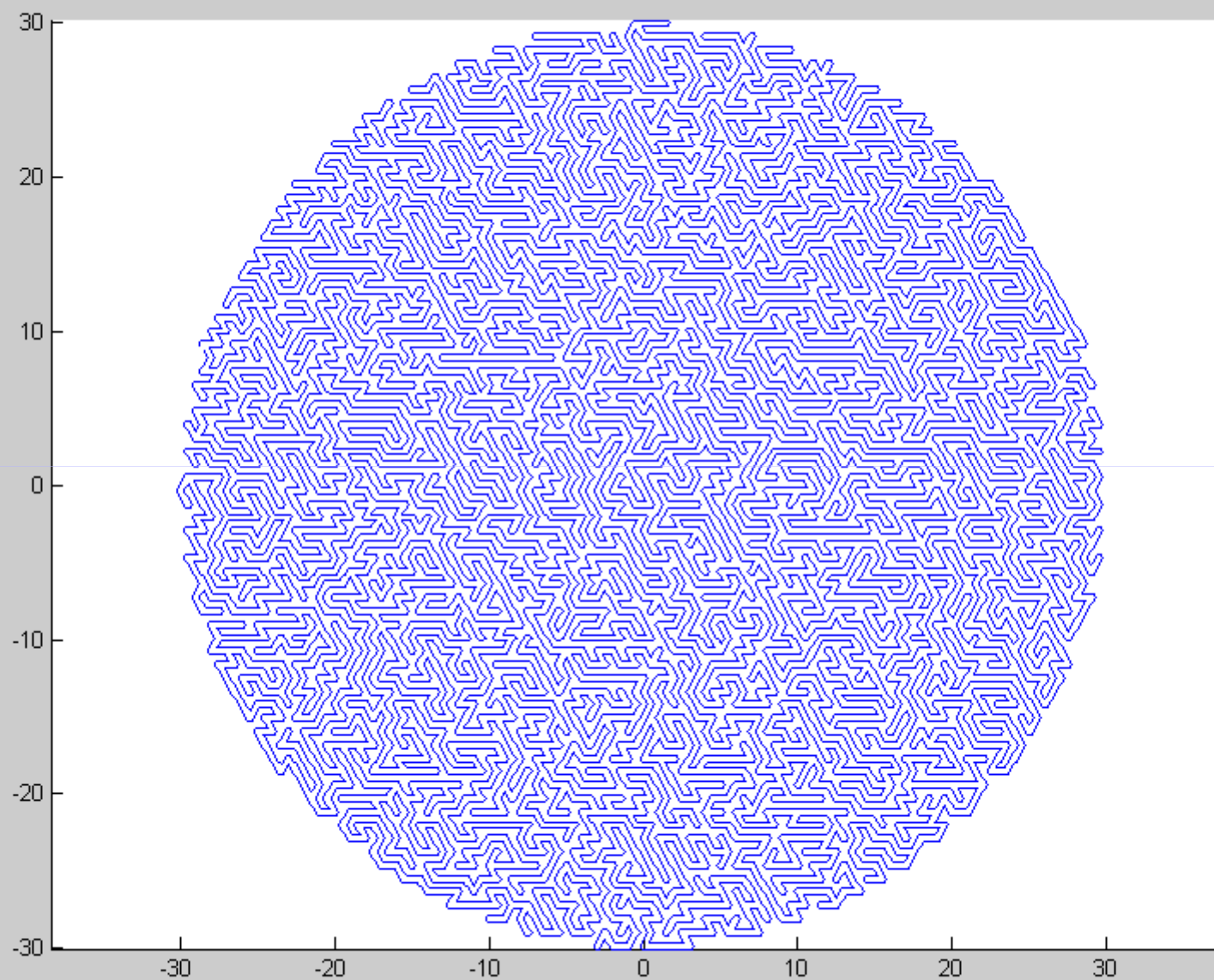
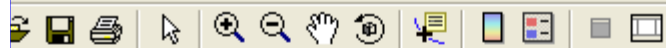
None



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Edit View Insert Tools Desktop Window Help



**Surface Statistics:**

Ra: 415.81 nm

Rq: 441.29 nm

Rz: 1.29  $\mu\text{m}$

Rt: 1.30  $\mu\text{m}$

**Set-up Parameters:**

Size: 736 X 480

Sampling: 160.71  $\mu\text{m}$

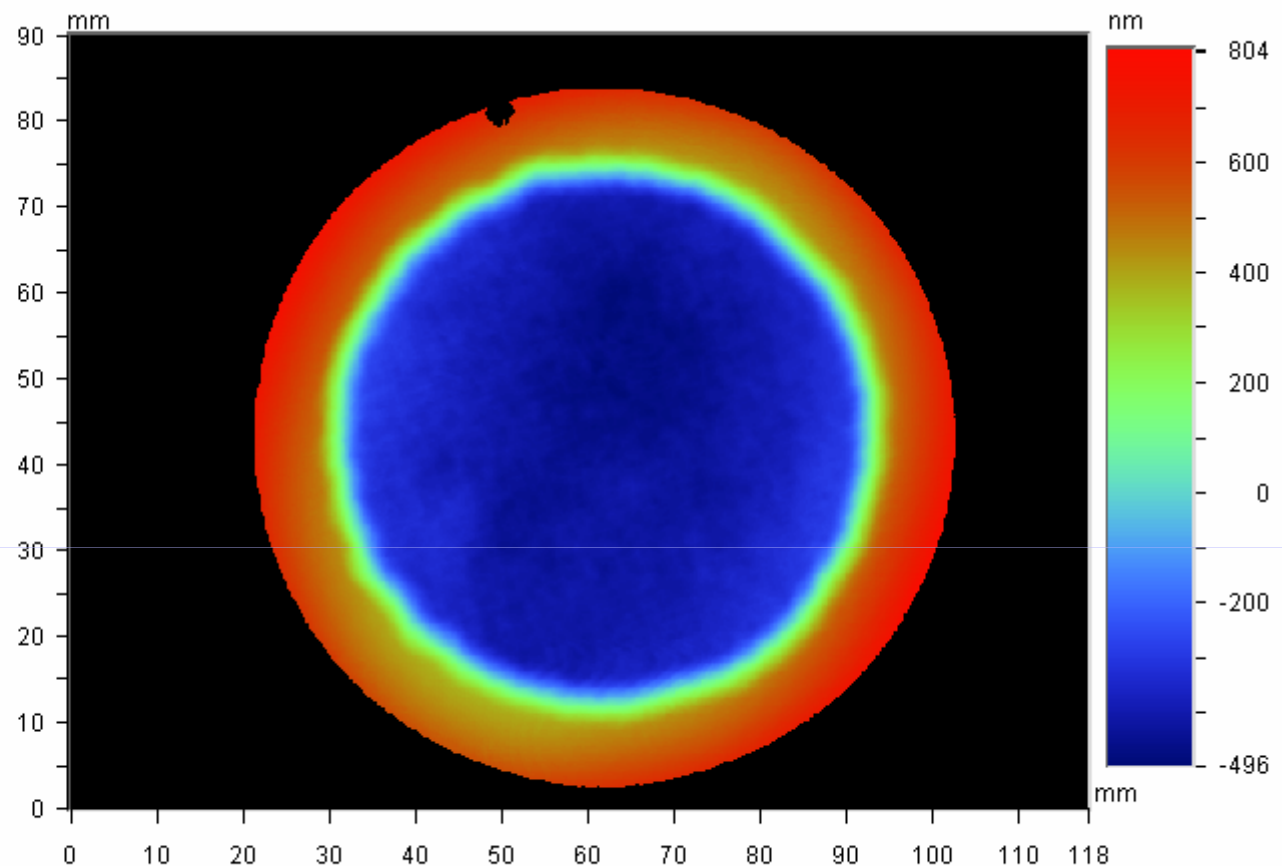
**Processed Options:**

Terms Removed:

Tilt

Filtering:

None



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**Surface Statistics:**

Ra: 318.52 nm

Rq: 332.92 nm

Rz: 804.54 nm

Rt: 814.19 nm

**Set-up Parameters:**

Size: 736 X 480

Sampling: 160.71 um

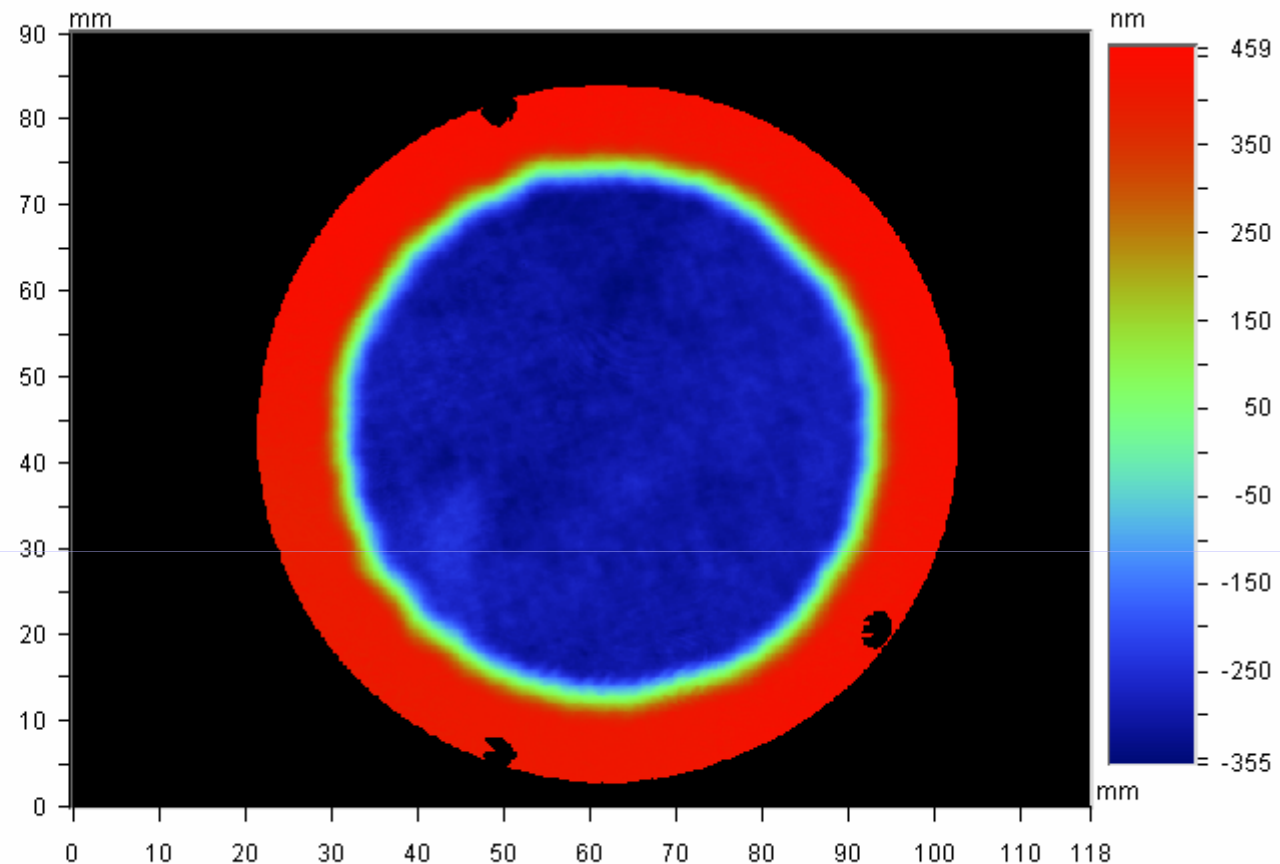
**Processed Options:**

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Filtering:

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**Surface Statistics:**

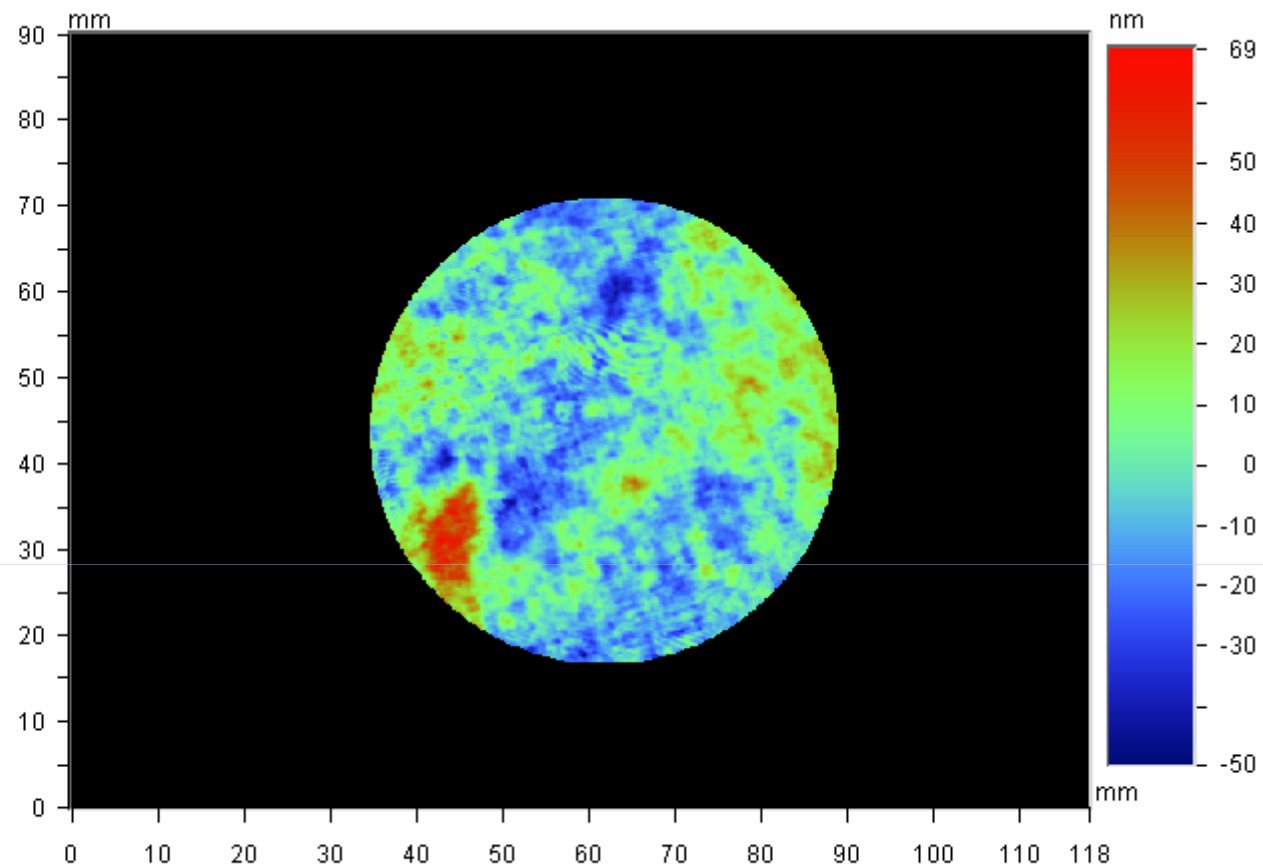
Ra: 11.56 nm  
Rq: 14.94 nm  
Rz: 102.68 nm  
Rt: 118.34 nm

**Set-up Parameters:**

Size: 736 X 480  
Sampling: 160.71  $\mu\text{m}$

**Processed Options:**

Terms Removed:  
Tilt  
Filtering:  
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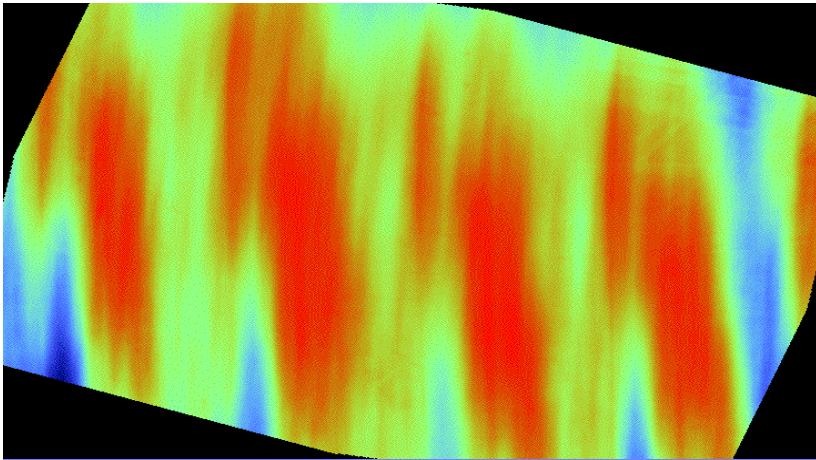


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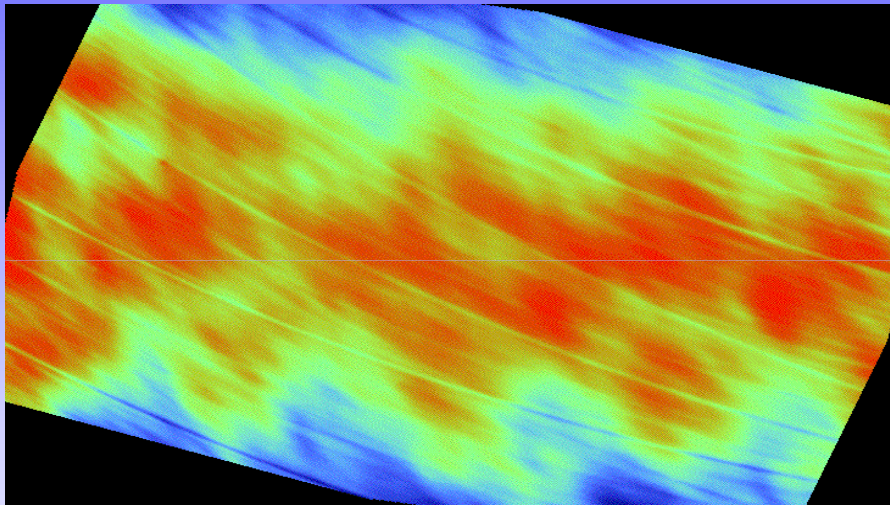
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# Clean up experiment with random tool path

- Glass flat was polished with a raster path to produce a surface with a periodic mid-spatial frequency feature.
- This region was then re-polished twice using random tool paths, resulting in an improvement in surface texture.

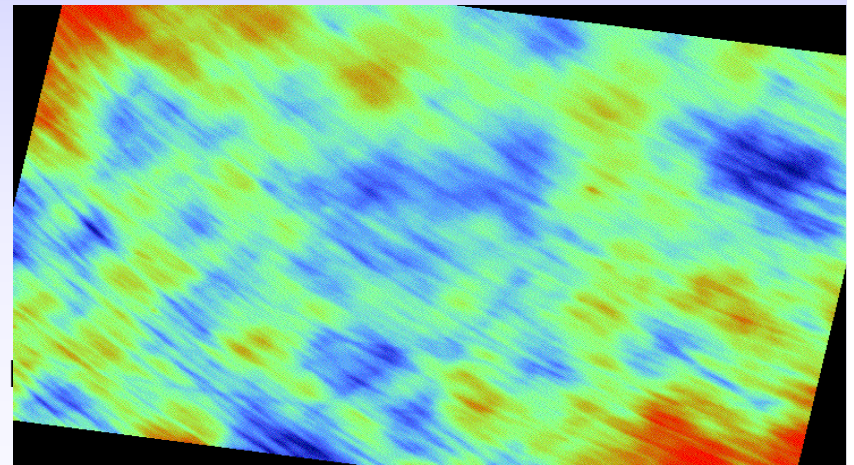


Surface after  
raster polish



Surface after 1st  
random polish

Surface after  
2nd random  
polish



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# Surface texture statistics

	Ra (nm)	Rq (nm)	Rt (nm)
Rastered surface	8.10	10.29	114.47
After 1st random polish	6.55	7.85	43.37
After 2nd random polish	3.95	5.24	35.21

# Uniform removal

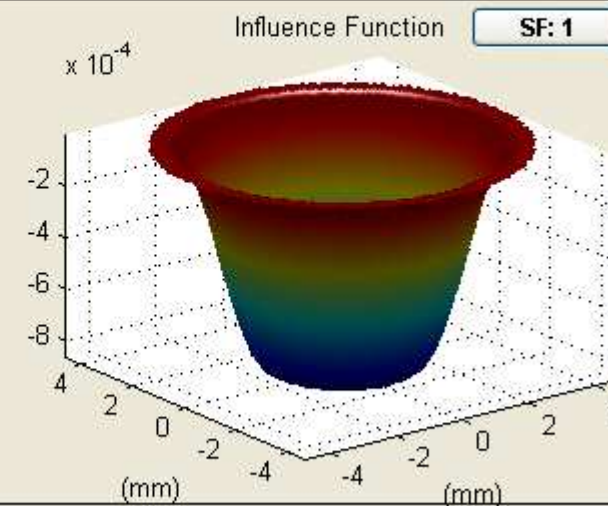
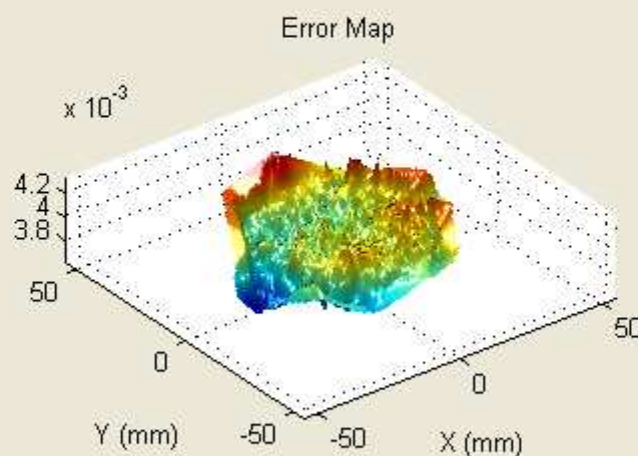
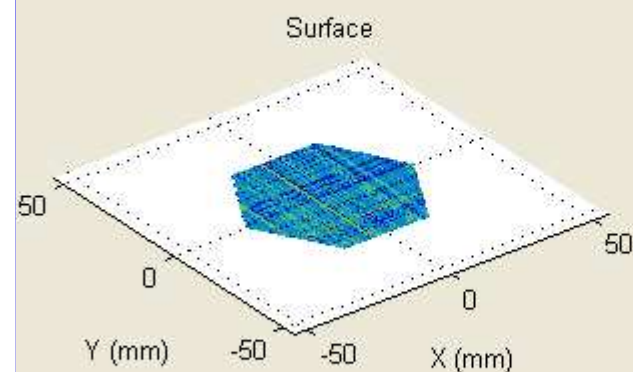
- For pre-polishing, we need a higher removal rate
  - Experiments are planned to find parameters that maximize the removal rate
- For a clean up step, we need a better finish
  - Experiments are planned to repeat this same procedure with a pitch tool

# Correcting with the Random Tool Path

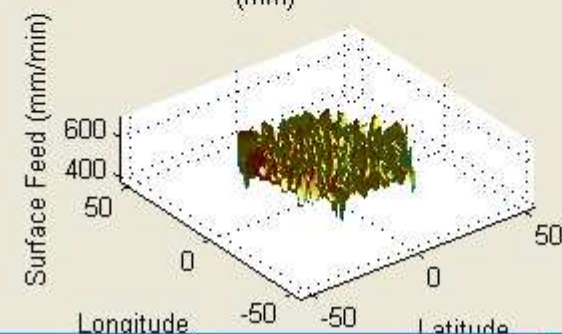
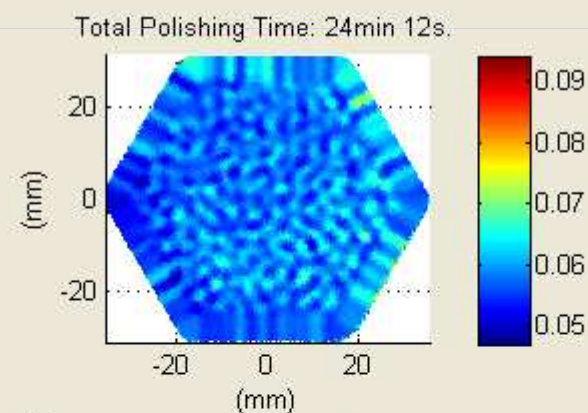
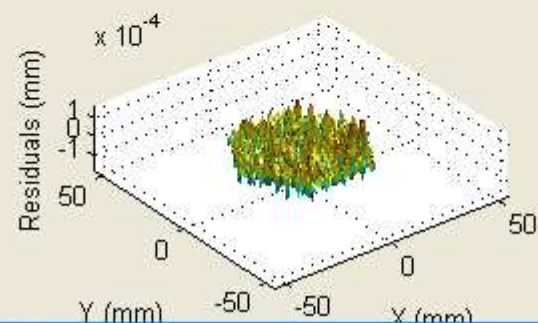
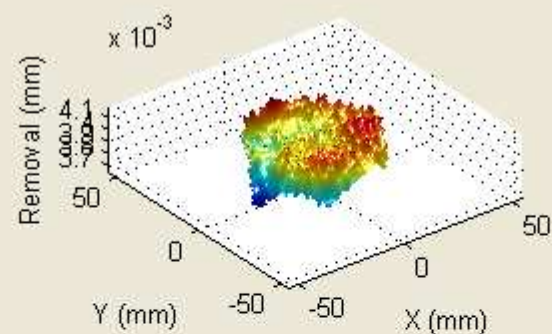
- Successful correction of surfaces with the random tool path depends on the ability to deliver the correct dwell times at the correct locations.
- Zeeko's *Precessions* software is capable of optimizing dwell time maps to produce very complex corrections.

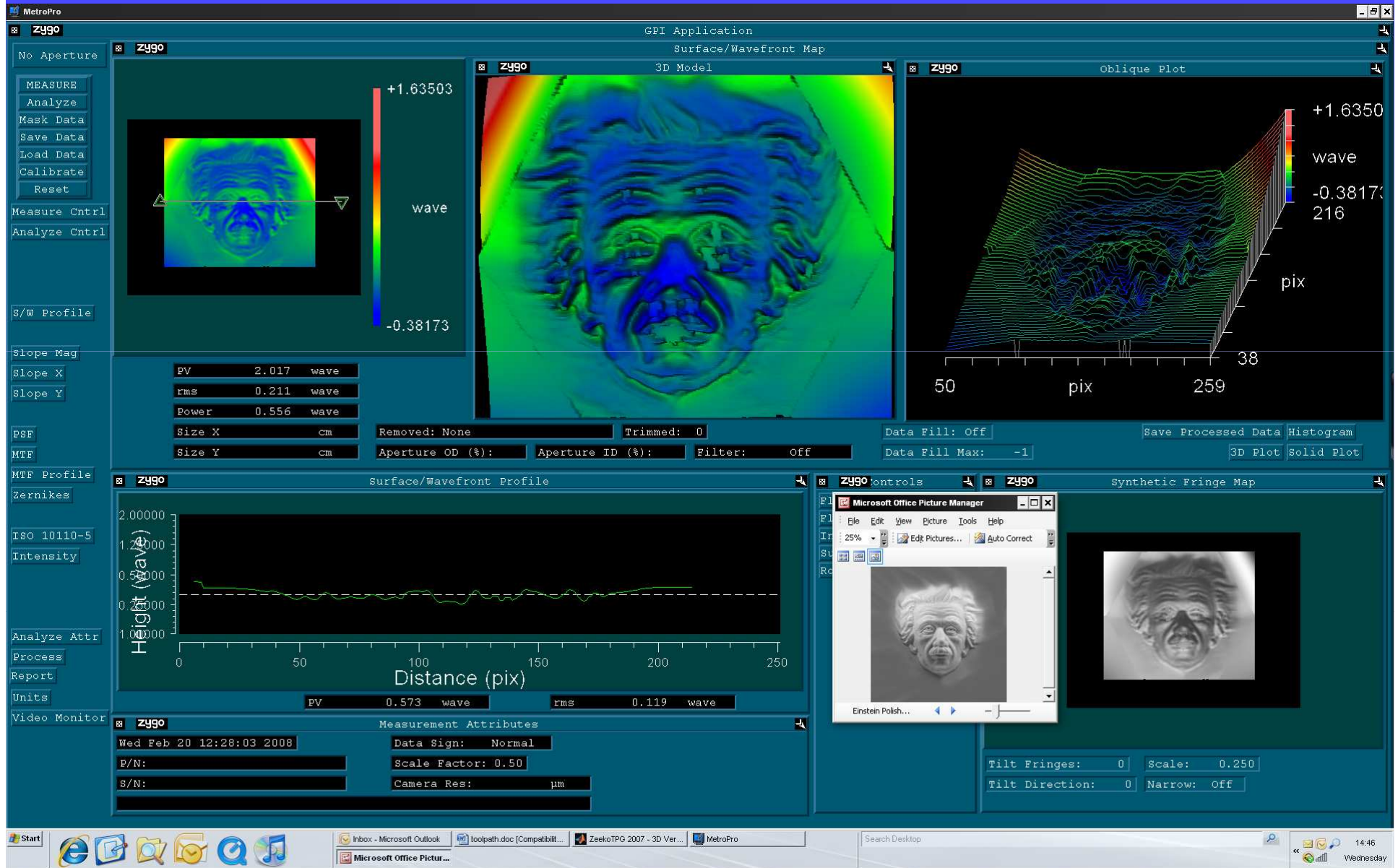


# Optimisation Setup



# Optimisation Result





**Surface Statistics:**

Ra: 275.14 nm

Rq: 317.78 nm

Rz: 1.17  $\mu\text{m}$

Rt: 1.18  $\mu\text{m}$

**Set-up Parameters:**

Size: 736 X 480

Sampling: 0.00 nm

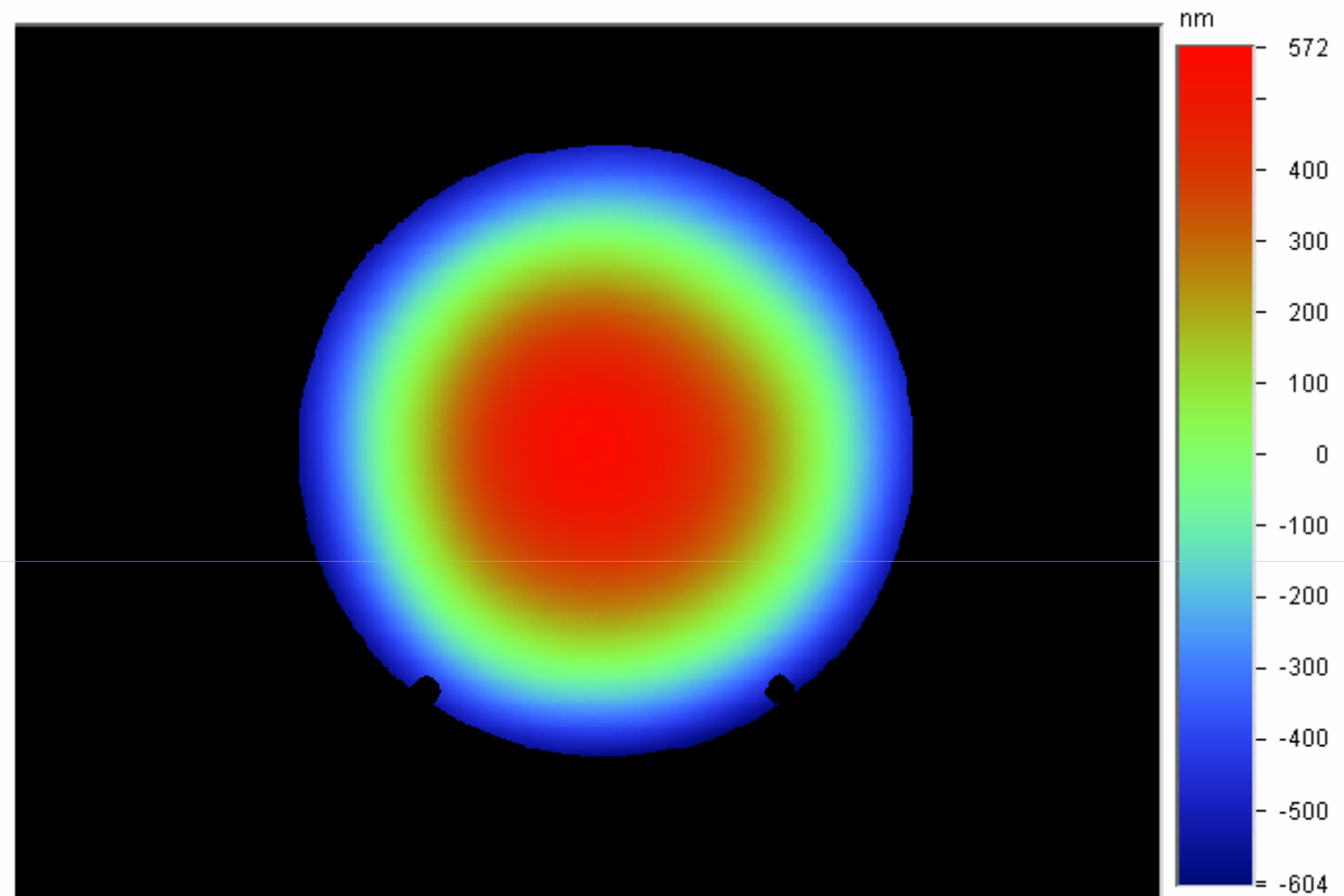
**Processed Options:**

Terms Removed:

Tilt

Filtering:

None



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**Surface Statistics:**

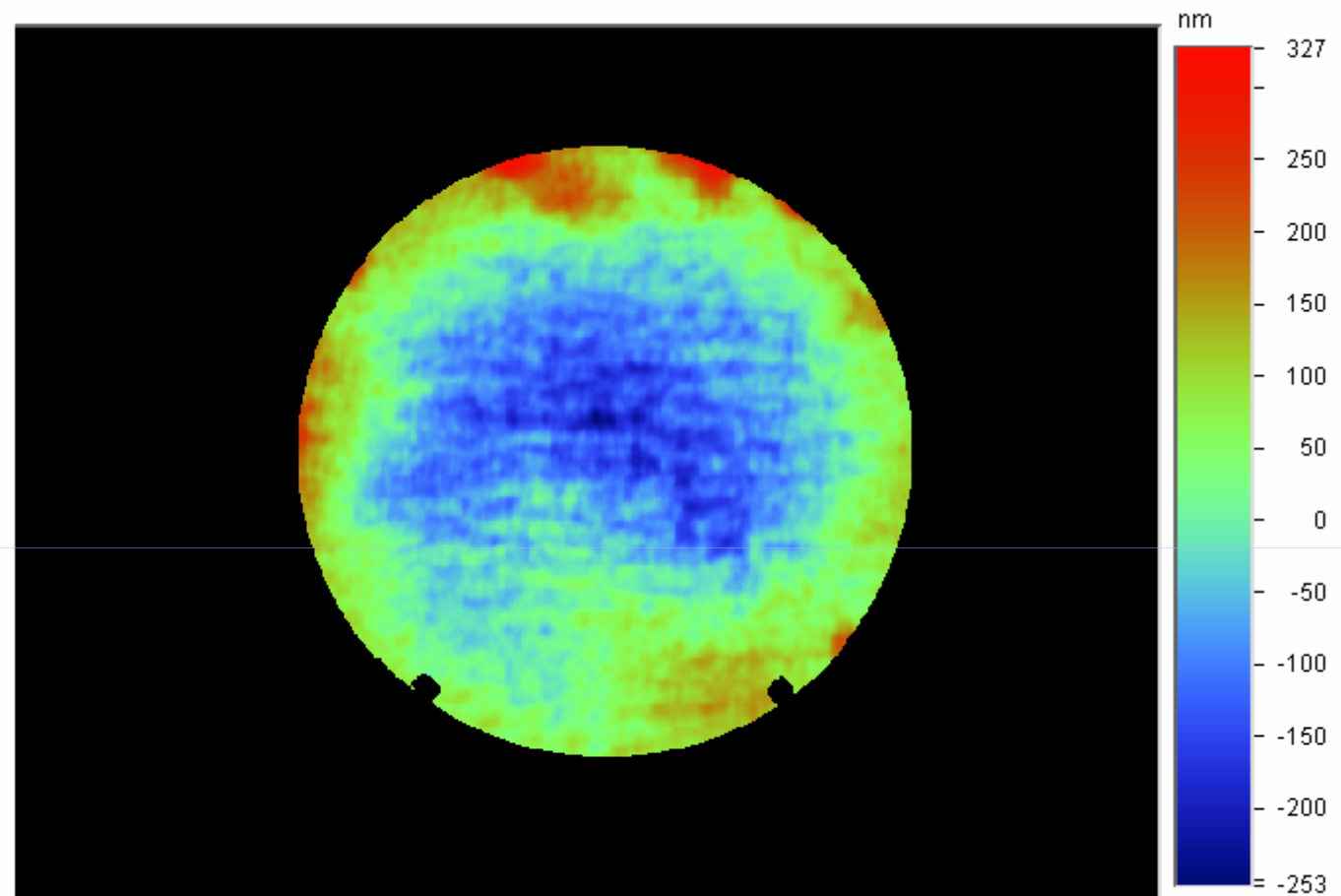
Ra: 73.15 nm  
Rq: 88.73 nm  
Rz: 510.98 nm  
Rt: 579.64 nm

**Set-up Parameters:**

Size: 736 X 480  
Sampling: 0.00 mm

**Processed Options:**

Terms Removed:  
Tilt  
Filtering:  
None



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**Surface Statistics:**

Ra: 29.92 nm

Rq: 40.62 nm

Rz: 367.56 nm

Rt: 429.68 nm

**Set-up Parameters:**

Size: 736 X 480

Sampling: 0.00 mm

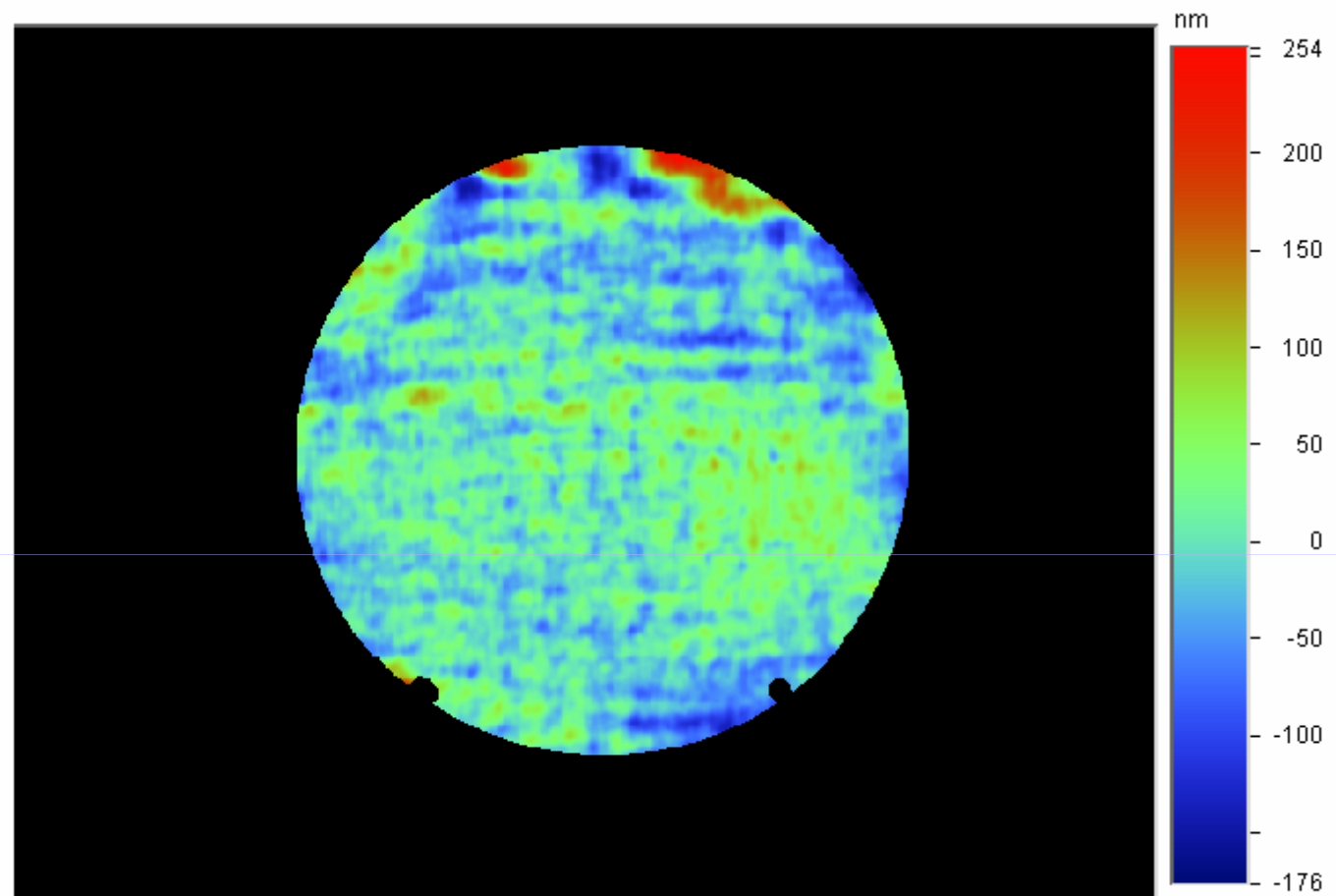
**Processed Options:**

Terms Removed:

Tilt

Filtering:

None



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# Correcting with Random Tool Path

- At the moment, the application of the dwell time map using the random tool path is not accurate enough to produce results which rival the Zeeko process with a raster tool path.
- Both the accuracy of position and velocity tool must be improved during the random polish.

# Conclusions and Future Work

- The most viable use of the random tool path is the clean-up step, requiring testing with a pitch tool and better slurry delivery.
- The next application to develop is pre-polishing, requiring increasing the removal rate.
- The processes could be used in concert with the standard tool paths, using these tool paths for correction and random for pre- and post-processing.

# Acknowledgements

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